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Estimates of annual food consumption/biomass ratio (Q/B) from the fish fauna of a mangrove estuary in North Brazil

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ABSTRACT. To contribute to mass balanced trophic model parametrization, estimates of annual food consumption/biomass ratio (Q/B) were compiled for 37 selected fish species of the Curuçá Estuary in Northern Brazil using an empirical model. Samples were taken bimonthly between July 2003 and July 2004 in the main channel and intertidal creeks using an otter trawl and a fyke net, respectively. The aspect ratio of the caudal fin varied between 0.8 for *Poecilia vivipara* and 4.6 for *Sciades herzbergii* and the Q/B ranged from 2.3 for *Epinephelus itajara* to 67.3 for *Cetengraulis edentulus*. This study represents the first reference available on Q/B values of 29 fish species. This compilation of Q/B ratio presented here should be useful for construction of Ecopath models particularly in tropical conditions.

Keywords: consumption/biomass; aspect ratio; trophic models; Ecopath.

RESUMO: Estimativas das relações de consumo de alimentos por unidade de biomassa (Q/B) da ictiofauna de um estuário do Norte do Brasil. Para contribuir para a construção de um modelo de balanço trófico, as estimativas das relações de consumo de alimentos por unidade de biomassa (Q/B) foram compiladas para 37 espécies de peixes do estuário do Curuçá selecionados no Norte do Brasil usando um modelo empírico. As amostras foram coletadas bimestralmente entre Julho de 2003 e Julho de 2004 no canal principal e áreas intertidais usando uma rede de arrasto modelo "otter trawl" e uma rede "fyke", respectivamente. O aspect ratio da nadadeira caudal variou entre 0,8 para *Poecilia vivipara* e 4,6 para *Sciades herzbergii* e o Q/B variou de 2,3 para *Epinephelus itajara* para 67,3 para *Cetengraulis edentulus*. Este estudo representa a primeira referência disponível dos valores de Q/B para 29 espécies de peixes. Esta compilação de Q/B deveria ser utilizada para a construção de modelos de Ecopath específicos para condições tropicais.

Palavras-chaves: consumo/biomassa; aspect ratio; modelo trófico; ictiofauna; Ecopath.

1. Introduction

One of the most important aspects of ecological studies lies in understanding the ecosystems through their trophic fluxes with regard to energy assimilation, transfer and dissipation (BAIRD; ULANOWICZ, 1993). During the last 50 years, indiscriminate fishing gear and unsustainable fishing practices have led to significant and steady decline in the mean trophic levels of fishery landings (PAULY et al., 2000). The global fishery collapse was observed over the last decades and its highly complex impacts on ecosystems have contributed to the substitution of the traditional single-species assessments for a more holistic approach: the "ecosystem-based management" (e.g. JENNINGS; POLUNIN, 1996; PAULY, 1998; CHARLES, 2001; JACKSON et al., 2001).

The Ecopath software (POLOVINA, 1984) has been widely used to describe trophic relationships in aquatic ecosystems on quantitative bases (PAULY et al., 2000). Information about feeding ecology and food consumption of the major functional groups of an ecosystem are necessary to construct mass and energy flow models (CHRISTENSEN; PAULY, 1993). Consumption is the intake of food by a species over a time period, expressed on an annual basis (CHRISTENSEN; PAULY, 1993). The food consumption per unit biomass (*Q/B*) indicates the number of times that a given population consumes its own weight per year (PAULY, 1986). However, estimates of *Q/B* ratio are lacking for most tropical fish species. Therefore, this study compiled food-consumption estimates (*Q/B*) of 37 fish species caught in a macrotidal mangrove estuary in Northern Brazil, with the aim to contribute to mass-balanced trophic models construction in similar ecosystems. These species constitute up to 95 % in terms of both total catch weight and abundance in the studied area (GIARRIZZO; KRUMME, 2007; VILAR et al., 2013). This study represents the first reference available on *Q/B* for 29 fish species.

2. Material and Methods

Sampling was carried out in the estuary of the Curuçá River, Pará, North Brazil, located at the eastern tip of the mouth of the southern channel of the Amazon delta (Marajó Bay) (0° 10' S, 47° 50' W) (Fig. 1). The climate is hot and humid with mean annual rainfall of 2,526 mm (ANA, 2005; n = 16 years, range: 1,085 – 3,647 mm).. Water temperature is constantly high with an average value of 26.7 °C. Salinity changes according to the season, being low during the rainy season, in the first half of the year and attaining values of marine water during the dry season. Like in the whole Northern Brazilian coast, the Curuçá estuary is fringed by mangrove forests composed of *Rhizophora mangle* L., *Avicennia germinans* (L.) and *Laguncularia racemosa* (L.). Tides in the region are characterized by a semi-diurnal pattern with a tidal range of 3 – 4 m at neap tides and 4 - 5 m at spring tides.

Samples were taken bimonthly between July 2003 and July 2004 at diurnal neap tides in the middle and upper estuary. To collect fishes from the main channel (3-7 m deep at low tide), 112 samples, distributed between eight sites (Figure 1), were taken with an otter trawl of 8.62 m width and 13 mm stretched mesh size (for details see VILAR et al., 2013). In addition, the intertidal fish fauna was collected using a fyke-net with 13 mm stretched mesh size placed at the mouth of four tidal creeks yielding a total of 28 samples (for details see GIARRIZZO et al., 2010).

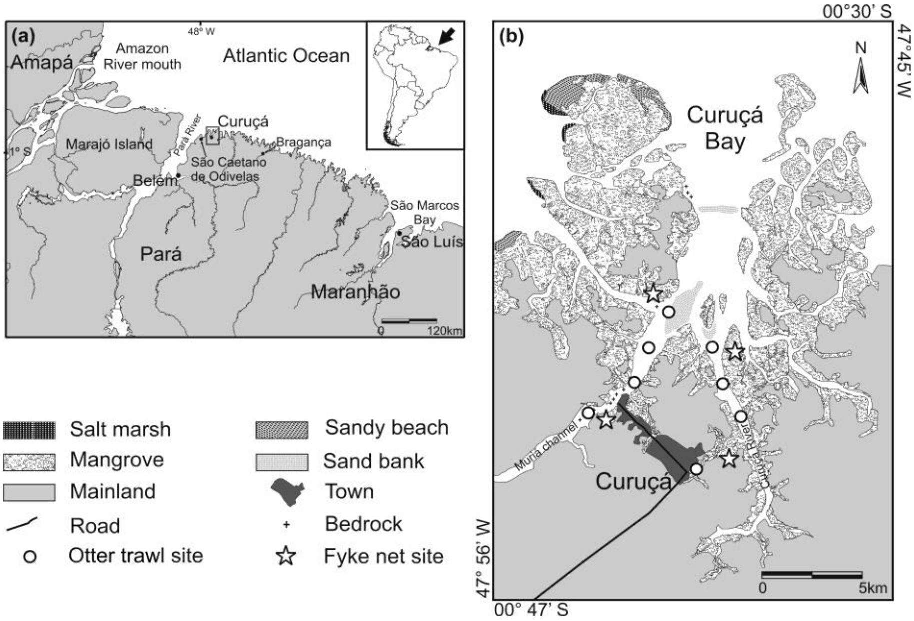

Figure 1. Map of study location showing sampling sites.

After collection, the fish were preserved on ice up to the laboratory where they were identified, total length measured (mm) and weighed (g). *Q/B* values for each fish population were estimated using the empirical model of Palomares & Pauly (1998):

$$Q/B = 10^{(7.964 - 0.204 \log w\infty - 1.965T + 0.083A + 0.532h + 0.398d)}$$

where: *Q/B* is the annual food consumption/biomass ratio; $W\infty$ is the asymptotic wet weight in g of the population calculated according to the relationship: $W\infty = W_{max}/0.86$ (PAULY, 1984), where W_{max} is the weight of maximum sizes fish caught (g); T is the mean habitat temperature expressed as $1,000/[T(°C) + 273.1]$; A is the aspect ratio of the population caudal fin, defined by the ratio: $A = h^2/S$, where, h and S are the height and surface area of caudal fin, respectively; h and d represent the feeding type ($h = 1$ and $d = 0$ for herbivores; h = 0 and d = 1 for detritivores; h = 0 and d = 0 for carnivores).

For each fish species, a random sub-sample of at least 50 fish was pooled to estimate the caudal fin aspect ratio. The software Scion Image was used to capture, display and analyze the drawings and subsequently measure with graphical interface, the height and the surface area of the caudal fins.

The Q/B ratios for those fish species that occurred exclusively as juveniles were estimated using the W_{max} available in FishBase (FROESE; PAULY, 2013). When only the L_{max} was available in FishBase, the W_{max} was estimated using weight-length relationships according to Giarrizzo et al. (2006).

3. Results and discussion

A total of 1,877 specimens representing 37 species belonging to 21 families were analyzed (Table 1). The caudal fin aspect ratio values ranged from 0.8 for *Poecilia vivipara* (Bloch & Schneider, 1801) to 4.6 for *Sciades herzbergii* (Bloch, 1794). According to Palomares & Pauly (1989) fish species with a high swimming activity and consequently, high metabolic rates, frequently have caudal fins with higher *A* values, while sedentary fish, that presumably have a relatively lower food intake, are characterized by caudal fins with low values of *A*. For instance, *S. herzbergii* with an elongated body shape, short paired fins and a convex caudal fin is an active benthic feeder that needs high speed with quick acceleration to attack especially soft bottom preys. On the other hand, *P. vivipara*, a sedentary benthopelagic fish with a sub-cylindrical body shape and a round caudal fin, is a zooplanctivorous species that does not require much energy to feed. According to Isaac & Moura (1998) fish caudal fin shape is strongly related to swimming ability and metabolic needs.

Table 1. Estimates of the annual food consumption/biomass ratio (*Q/B*) of 37 fish species collected in mangrove estuary of the Curuçá River, Pará, North Brazil. For the fish species that occurred only as juveniles, the literature values of maximum total length (Lt_{max}) and maximum weight (W_{max}) of adults are indicated in parentheses. N: sample size; A: aspect ratio of the caudal fin; h and d: feeding type code according to Palomares & Pauly (1998).

Family / species	N	Lt_{max} (cm)	W_{max} (g)	$W\infty$ (g)	*h*	*d*	*A*	*Q/B*
Achiridae								
Achirus lineatus (Linnaeus,1758)	50	24.1	239.7	278.7	0	0	1.2	10.3
Anablepidae								
Anableps anableps (Linnaeus, 1758)	50	26.4	175.79	204.2	1	0	1.3	38.0
Ariidae								
Cathorops agassizii (Eigenmann & Eigenmann, 1888)	50	26.5 (32.0)	134.5 (328.6*)	382.1	0	0	3.0	13.5
Cathorops spixii (Agassiz, 1829)	53	19.0 (30.0)	59.6 (247.9*)	288.3	0	0	2.8	13.8
Sciades herzbergii (Bloch, 1794)	52	35.1 (54.0)	410.0 (1500.0)	1744.2	0	0	4.6	13.5
Atherinopsidae								
Atherinella brasiliensis (Quoy & Gaimard, 1825)	53	14.5	25.4	29.5	1	0	1.7	60.6
Auchenipteridae								
Pseudauchenipterus nodosus (Bloch, 1794)	53	15.5 (22.0)	39.3 (114.3*)	132.9	0	0	3.7	19.2
Bathrachoididae								
Batrachoides surinamensis (Bloch & Schneider, 1801)	50	37.8 (57.0)	800.0 (2300.0)	2674.4	0	0	1.2	6.5
Carangidae								
Chloroscombrus chrysurus (Linnaeus, 1766)	50	30.5		300.0	0	0	3.5	15.8
Oligoplites saurus (Bloch & Schneider, 1801)	50	20.8 (35.0)	62.6 (287.0)	333.7	0	0	3.4	15.1
Centropomidae								

Centropomus pectinatus Poey, 1860	52	20.4 (56.0)	95.1 (1507.0)	1752.3	0	0	2.4	8.8
Centropomus undecimalis (Bloch, 1792)	50	36.5 (140.0)	389.2 (24300.0)	28255.8	0	0	2.4	5.0
Clupeidae								
Odontognathus mucronatus Lacepède, 1800	50	14.3	9.9	11.5	0	0	2.2	23.8
Rhinosardinia amazonica (Steindachner, 1879)	50	15.6	32.2	37.4	0	0	3.6	24.4
Cynoglossidae								
Symphurus plagusia (Bloch & Schneider, 1801)	50	25.0	93.7	109.2	0	0	1.0	12.0
Engraulidae								
Anchoa hepsetus (Linnaeus, 1758)	50	15.0	29.5	34.3	0	0	2.1	18.6
Anchovia clupeoides (Swainson, 1839)	50	17.3 (30.0)	46.5 (227.4*)	264.4	0	0	4.2	18.4
Cetengraulis edentulus (Cuvier, 1829)	50	26.0	90.6	105.3	1	0	3.6	67.3
Lycengraulis grossidens (Spix & Agassiz, 1829)	50	18.2 (23.5)	54.3 (95.6*)	111.2	0	0	2.8	16.8
Pterengraulis atherinoides (Linnaeus, 1766)	51	21.6 (30.0)	74.2 (199.0*)	231.4	0	0	3.4	16.2
Gerreidae								
Diapterus auratus Ranzani, 1842	52	17.7 (34.0)	87.5 (680.0)	(790.7)	0	0	3.7	13.3
Haemulidae								
Genyatremus luteus (Bloch, 1790)	50	24.9 (37.0)	284.3 (800.0)	(930.2)	0	0	2.3	9.9
Hemirhamphidae								
Hyporhamphus roberti (Valenciennes, 1847)	51	13.1 (32.0)	5.6 (127.8*)	148.6	0	0	1.5	12.3
Lutjanidae								
Lutjanus jocu (Bloch & Schneider, 1801)	51	31.5 (128.0)	720.0 (28600.0)	(33255.8)	0	0	2.0	4.5
Mugilidae								
Mugil curema Valenciennes, 1836	50	33.1	577.1	671.0	1	0	2.8	39.6
Mugil rubrioculus Harrison, Nirchio, Oliveira, Ron & Gaviria, 2007	50	23.5	121.5	141.3	1	0	2.3	49.4
Mugil incilis Hancock, 1830	50	38.5	529.2	615.4	1	0	3.1	42.6
Paralichthyidae								
Citharichthys spilopterus Günther, 1862	50	12.0 (20.0)	10.2 (72.3*)	84.1	0	0	1.2	13.1
Poeciliidae								
Poecilia vivipara (Bloch & Schneider, 1801)	54	5.4	2.7	3.0	0	0	0.8	23.9
Sciaenidae								
Cynoscion acoupa (Lacepède, 1801)	50	27.0 (110.0)	175.4 (17000.0)	(19767.4)	0	0	1.3	4.4
Stellifer microps (Steindachner, 1864)	52	18.8	105.8	123.0	0	0	1.5	12.8
Stellifer naso (Jordan, 1889)	52	20.0	119.2	138.6	0	0	1.6	12.8
Stellifer rastrifer (Jordan, 1889)	51	20.0	142.3	165.5	0	0	1.3	11.6
Stellifer stellifer (Bloch, 1790)	50	14.6	56.7	65.9	0	0	1.5	14.6
Serranidae								
Epinephelus itajara (Lichtenstein, 1822)	50	32.1 (250.0)	625.9 (455000.0)	(529069.8)	0	0	1.5	2.3
Tetraodontidae								
Colomesus psittacus (Bloch & Schneider, 1801)	50	32.6	955.3	1110.8	0	0	1.9	8.8
Sphoeroides testudineus (Linnaeus, 1758)	50	18.3 (38.8)	181.6 (400.0)	(465.1)	0	0	1.8	10.3

Species in bold have annual food consumption/biomass ratio (*Q/B*) estimated in previous studies.
* Estimation of *Wmax* from literature value of *Ltmax*, using the weight-length relationship available for the same estuary (GIARRIZZO et al., 2006).

The annual food consumption/biomass ratio (*Q/B*) of 37 fish species collected in the macrotidal mangrove estuary of the Curuçá River varied between 2.3 for *Epinephelus itajara* (Lichtenstein, 1822) to 67.3 for *Cetengraulis edentulus* (Cuvier, 1829). The proportion of plants in the diet directly influences the food consumption (GARCIA; DUARTE, 2002). Mean *Q/B* values (±SD) of herbivorous and carnivorous was 48.6 ± 13.3 (range: 32.1 – 67.3), and 13.1 ± 5.6 (range: 2.3 – 24.4), respectively.

The trophic level of fishes usually tends to reflect different energy requirements to obtain food. Detritivorous and planktivorous fish such as engraulids have a low energy intake and high *Q/B* ratios while ichthyophagous and benthophagous fish have high energy requirements and low *Q/B* ratios, for example species like *E. itajara* and *Centropomus undecimalis* (Bloch, 1792). Therefore, an inverse relationship was observed between the energy intake and its transformation in biomass.

Values of *A*, temperature, asymptotic wet weight and *Q/B* calculated according to the empirical model of Palomares & Pauly (1998), are shown in Table 2 to allow comparison of results with other studies. The observed differences among localities could be explained by a number of factors including temperature, environmental conditions and methods used to measure the height and surface area for the calculation of *A*.

Table 2. Annual food consumption/biomass ratio (*Q/B*) of species from the literature.

Family / species	*A*	T (°C)	*W∞* (g)	*Q/B*	Location	Source
Achiridae						
Achirus lineatus	1.5	27.2	87.2	14.2	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)
Ariidae						
Cathorops spixii	1.5	28.8	314.0	11.9	Caeté estuary, Northern Brazil	Isaac & Moura (1998)
	2.4	25.7	233.5	12.7	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)
Carangidae						
Chloroscombrus chrysurus	4.1	26.4	388.4	16.4	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)
Oligoplites saurus	3.4	26.0	287.0	15.0	Tamiahua coastal lagoon, México	Abarca-Arenas & Valero-Pacheco (1993)
Gerreidae						
Diapterus auratus	3.2	27.6	581.4	13.6	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)
Lutjanidae						
Lutjanus jocu	1.4	26.9	7441.9	5.5	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)
Sciaenidae						
Stellifer rastrifer	1.1	28.8	162.0	12.5	Caeté estuary, Northern Brazil	Isaac & Moura (1998)
Serranidae						
Epinephelus itajara	1.1	28.0	814.0	8.6	Gulf of Salamanca, Colombia	Garcia & Duarte (2002)

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